SELECTED ARTICLES

ON ANIMAL BREEDING*

OBJECTIVES—The purpose of animal breeding is to meet a social demand for some particular commodity or service, *e.g.*, an animal product of a certain kind and quality, an animal so constructed as to be able easily to perform a certain task, or so decorative or quaint as to please.

The objective in animal breeding is the creation and maintenance of types which, in their characterizations, are in complete harmony with their destinies —the purposes for which they are bred. But since every detail of structure and function is the end-result of the interplay, during the individual's development, of heredity and environment, it follows that the breeder is concerned not only with the type and destiny of his animals but also and at all times with their habitat, the conditions under which they live. Type, habitat, and destiny must always be harmoniously related ; each reacts with and upon the others, and any considerable modification of any one of them must necessarily be followed by repercussions of equal magnitude among the rest. The purpose of breeding must be reasonable, not merely economically but also and especially biologically ; the environment must be optimum, free from all agencies, living and non-living, which cause defect and derangement, and such as encourages the full expression of all advantageous inborn potentialities ; the type must be the ideal, that most easily able to profit fully from the optimum environment provided and to yield the commodity or service demanded of it.

Since from time to time and from place to place social demands change and vary, the breeder is set the task of maintaining either a diversity of types, each harmonized to a particular habitat and/or destiny, or else a " flexible " type which by modifications in husbandry and/or breeding practice can quickly be remodelled.

Since also, and at the present time, animal stocks are maintained in places and under conditions which are such as to make the biologically optimum environment unattainable, the objective in animal breeding commonly comes to be the creation and maintenance of animal types that are in harmony with the best environment which, under the conditions, it is economically possible to create.

---

* By Prof. F. A. E. Crew, M.D., D.Sc., Ph.D., of the Institute of Animal Genetics, University of Edinburgh, in *The Empire Journal of Experimental Agriculture*, Vol. VII., No. 25, January, 1939. Reproduced by kind permission of Prof. Crew and the Editor of *The Empire Journal of Experimental Agriculture*.

At the present time, for reasons which are rooted in economic necessity, animal stocks are being maintained in habitats which are in every respect incurably harsh and entirely unsuitable. In the future, when reason controls our activities, perhaps animal-breeding planning will ensure that animals are bred where they most easily breed and thrive. For the present we must content ourselves with the production of types that give the best performance under given conditions, whilst all the time we strive to improve these conditions.

If in any given region a uniform environment exists, then as this approaches the optimum there will be a reduction in the number of types that are needed, and the few that remain will show uniformity and will become relatively fixed, whereas in a region which includes a variety of environments a lower degree of uniformity and a greater degree of adaptability will be required.

At all times and in all places the breeder must maintain a high reproductive rate and a low mortality rate, for he is concerned not only with productivity of his stock but also with its reproductivity and its viability.

It is recognized that policies of live-stock improvement necessarily involve synchronized improvement in destiny (marketing), in habitat (husbandry, including nutrition and disease prevention), and in type (the genetical constitution of the stock, breeding systems, standards). Though on occasion specialists may consider these different aspects of one and the same problem separately the breeder himself in practice can never hope to disentangle them, nor should he wish to do so.

These are the views of a biologist who sees the world through the window of a laboratory. It may be that the windows distort that which is seen, or protect the onlooker from the fierce winds of financial anxiety. Be this as it may, the fact remains that the breeder is also an experimental biologist, and that his success or failure is determined less by his financial acumen than by his biological expertness. This being so, it may be mutually profitable for biologists to commune.

The Fowl.—To give point to these views any one of us could choose a convenient example. I propose to use the fowl, because it has been my collaborator in many an experiment; but the fowl is merely an illustration of all live stock. Society demands a 2-oz. egg (with a white shell and at a certain price). Thus the purpose of poultry-breeding for egg production is the provision of this 2-oz. egg. But in order to meet this demand, and in so doing to secure an adequte reward (according to the standards of our own society), the breeder has to create and maintain a stock of fowls which will mature in less than seven months (*i.e.* he has to be able to control growth-rate, bodily maturity, and puberty); that will convert say 95 lb. of food into 200 such eggs (he is concerned with the genetical and physiological aspects of efficiency of food-utilization and of fecundity); that will show a fertility rate of at least 85 per cent. (he must know a great deal about the genetical and physiological aspects of fertility); that will show a mortality rate of not more than 10 per cent. (disease-resistance, disease-prevention, viability); and that is of such a quality that about two-thirds of the stock can be profitably retained for a second year of production (he must

know all that is known concerning the factors affecting the duration of productive life). These are the objectives in breeding, and be it noted every one of them must be gained and held contemporaneously if the breeder is to build a type that is in harmony with its destiny.

The demand for a 2-oz. egg is reasonable, for it has been shown that the hen can produce 200 or more of these without harm to herself or to her progeny. The objectives are all concerned with biological variables, relating to which a considerable body of scientific knowledge exists. None of them refers to any particular breed trademark, for the breeder of utility poultry at least knows that there is no such thing as the best breed, though of course he will quite rightly maintain that a certain type (a certain constellation of genetic characters which may or may not include the few superficial characters of a particular breed) is best suited to a particular habitat and for a particular market. In fact " breed " no longer possesses any considerable importance to the utility breeder; good looks are less important than are the individual's own record of performance, the record of its relatives (pedigree), and the record of its offspring (progeny test). Brothers and sisters, and cousins and aunts are important people in the poultry world.

So many are the qualities that the breeder must maintain in his stocks, so varied are the mechanisms that underlie them, and so incomplete is our knowledge of them, that the general public should not be surprised to find that the breeders have not yet succeeded in doing all that they must do before the industry is placed on a satisfactory basis. It is probably correct to say that the average egg production per bird per year is around 80 eggs, and that these do not average 2 oz. in weight; that about 30 per cent. of all the eggs that are incubated fail to yield viable chicks; that the mortality among pullets is of the order of 20-80 per cent., and nearer 80 than 20; and that stocks must continuously be replaced for the reason that the duration of productive life is so brief. Productivity, reproductivity, and viability are all far removed from what they must be before poultry-breeding can be a profitable and pleasant occupation for breeders as well as for bureaucrats.

It is now recognized that, for a variety of reasons, the affairs of the poultry industry must become the concern of the State. The individual breeder and his organizations are not competent to deal with the complicated problems of disease-prevention, for example, and so these are now to be tackled and solved by a veterinary state service. The fowl is about to make its dramatic entrance into the veterinary curriculum: heretofore it has died miserably in its millions because pets have been rated higher than producers. Furthermore, professional scientists by the dozen are being employed to investigate those problems of husbandry, nutrition, and breeding which, for obvious reasons, cannot possibly be properly examined by the breeders themselves.

Possibilities of Genetic Improvement.—The geneticist should be welll content to be provided with the opportunity for using the fowl as experimental material. It is relatively cheaply maintained, its matings can be controlled, generation succeeds generation fairly rapidly, and it has numerous offspring. Moreover, the characters, the mode of transmission of which is to be studied, are on the

whole definite and easily recognized. In live stock generally it is the very indefiniteness of the characters to be studied, and the lack of knowledge concerning the forces affecting their expression, that make genetical experimentation so hopeless. It is very doubtful indeed that serious genetical investigation of meat qualities can be profitably undertaken until the work of Hammond has been greatly advanced and extended. It is useless to attempt to make a genetical study of the price of a pound of beef. Before genetical work can proceed the characters to be studied must be accurately described. Moreover, genetical work demands large numbers of animals, and so the geneticist waits upon further developments in the techniques of artificial insemination. Walton and Hammond are, by their work, creating the possibility for useful genetical experimentation with the larger domesticated animals in the near future. When the kind of work that Hammond and his colleagues are doing has advanced we shall be in a position to know how far the animal stocks we now possess are capable of being modelled by husbandry into the desired types. If they can be so modelled, then it will be revealed that they are in this respect genetically satisfactory ; if not, then by the application of genetical methods appropriate types must be created. We shall know the limits of modifiability and shall have a much clearer notion of what is genetic in these qualities of economic importance.

It will now be seen that there is an inherent difficulty in the conception of the ideal type having its being in the optimum environment. So many qualities are demanded (for example, high reproductive rate, a rapid growth-rate, tolerance to certain important deficiencies) that it seems very unlikely that one and the same environment can possibly be optimum for the full expression of all of them. Thus the optimum environment for high milk-yield might prove to be far removed from the optimum for a high degree of resistance to disease. However, on general grounds, it is reasonable to hold the view that it is possible, by appropriate methods, to bring together into one and the same hereditary constitution the genes for any combination of characters that have been shown to be genetic. But whether or not the characters corresponding to these genes can be fully expressed by any individual possessing them all, is a question that can only be decided by further experimentation. Physiological incompatibilities may prevent the creation of types exhibiting all the desired qualities expressed to the maximum degree. If this should prove to be so, then either the standard of the ideal must be modified, or other means of equipping the types with all the desired qualities must be devised.

In the meantime the geneticist has his part to play in helping the live-stock industry to concentrate on as small a number of objectives as possible, to rid itself of standards that are based on false methods of evaluating merit, and to develop better criteria for measuring and evaluating live stock and its products. He must also, and at all times, plead that comprehensive schemes of inbreeding should at once be launched for the purposes of genetical analysis and purgation of the stock, and of providing genetically satisfactory material for use in nutritional and other experimentation.

Whilst the methods and practices of the past have accomplished much, giving us the fine breeds of to-day, they seem to be reaching the limits of their usefulness. The past has been dominated by standards that seem now to be more or less unreal, sometimes even misleading, and commonly disregardful of the qualities that really matter—productivity, reproductivity, and viability. At the present time we have not disentangled the effects of the environment from those of heredity and so have no knowledge of the importance of either. Without such knowledge we cannot know whether modifications in husbandry or alterations in constitution offer the quickest and soundest means of further improvement.

We are unadventurous in breeding, breeders from necessity, for no private individual in our Society can afford to undertake experimentation that is certainly costly and probably in conflict with his own self interests; nor will the State, because those who guide our destinies are, for political reasons, more inclined to encourage projects which promise information concerning the possibilities of improving nutrition, general husbandry, and of lowering the incidence of diseases by the provision of sera and vaccines. While these are proceeding, and while the standards of the ideal are being refashioned and trustworthy yardsticks constructed, the job of the geneticist should be the creation of inbred stocks. Inbreeding to the live-stock industry is what track-racing is to the makers of motor-cars. It is the test of constitution, the revealer of hidden faults, the demonstration of ability beyond that ordinarily required. Through inbreeding, strains equipped with vigour and purged of all weakness, can be provided for breed-improvement programmes of the future. In order to know what underlies high milk-yield and high egg-yield we must have true-breeding, low-yielding strains. Further-more, it is not improbable that many of the ideal types of the future will be first crosses between two distinct inbred strains of the same breed.

Though the animal geneticist must wait upon developments in physiology, veterinary science, and husbandry before he can hopefully engage in large-scale experimentation with the bigger animals, even now, were he encouraged, he could make contributions of importance. It is established, for example, that in one and the same stock of laboratory animals families differing constantly and widely in respect of growth-rate, weight-for-age, and in efficiency of food-utilization can be developed. There is no doubt that these characteristics, so important in live-stock economy, are profoundly affected by heredity, and that they can be manipulated by the application of genetical principles. The correct breeding procedure for the production of similar strains of animals of economic importance have been elaborated and await use.

The rations now provided are so constituted that they give protection against shortage of any constituent known to be essential, no matter how extreme the variation among individuals may be with respect to their requirement of that constituent. Since some of these essentials are very expensive, such a practice as this may be a weighty burden. It might prove to be sound

policy to create by genetical methods, and this is the only way, strains in which the requirements of some of these more expensive accessory food factors and minerals are reduced to a minimum. In the fowl this objective has already been partly reached ; there are strains which are highly resistant to vitamin-B and manganese deficiencies. There is every reason to expect that strains of live stock remarkable for their tolerance of sub-optimal levels of any of these factors and minerals could easily be created.

Veterinary Research.—The veterinarian is primarily concerned with the eradication of the environmental causes of defect and derangement. His task is to wrench the sickle from the grisly hand of unnecessary death and place it in the fist of the butcher. But we have reason to know that the conquest of a plague may herald the coming of a pestilence. A particular disease makes its appearance, grows in importance, wanes and gives place to another, and the discovery of a cure commonly coincides with the expected disappearance of that disease as an important cause of death. We have " conquered " tuberculosis only to find that rheumatism is the real public enemy No. I. By the time we have learnt how to conquer rheumatism it, in its turn, will be giving place to something else. So it is to be expected that the veterinarian will " conquer " fowl paralysis, if sufficient time elapses before the cure is found. Having done so he will pass on, encouraged by his success and its associated rewards, to the conquest of its successor. His task is to gain the power of preventing all the serious diseases which affect the individual during the first half of its natural life span, for the diseases of senescence can be disregarded. It may be that the time has already arrived when more attention should be paid to the power of the individual to resist the attack of disease-provoking organisms. It is established, for example, that by appropriate genetical methods strains of fowls not only highly resistant to specific diseases but also markedly resistant to disease in general can be established. It is not for me to argue that it would be sound policy to attack the problem of disease in this way : I must content myself by saying that it can be done.

Genetical Research.—All defective derangements are, however, not caused by agencies external to the individual, many are the direct expression of constitutional peculiarities. Many lethal and semi-lethal genes are known to exist in live stock and to be directly responsible for the death or the profound debility of the individual in whose hereditary constitution they are present. In the fowl, for example, five such genes are the causes of much death during incubation, whilst two others are largely responsible for the peak of mortality which occurs within the first fortnight after hatching. Others are known to be the cause of pre- and early post-natal mortality in the pig, sheep, and cattle. It is not improbable that the elimination of these lethals might prove to be a most effective means of raising the reproductive rate and of lowering the mortality rate in many stocks. But before they can be eliminated they must be discovered, and so another reason for extensive programmes of inbreeding is provided.

If the causes of death among a poultry population are examined it is found that disorders of reproduction, *e.g.* ruptured oviduct, impacted oviduct, figure very highly. The prevalence of these conditions does not seem to be the direct

result of any increase in productivity, and it is difficult to see how they can be prevented by modifications of husbandry. It would seem that selection for egg-number and egg-size is not also selection for an oviduct that can cope with such production. The eye of the breeder has been fixed on the ovary, and the oviduct, which apparently demands special attention, is overlooked. It has been shown by Greenwood that the size and degree of development of the oviduct are dependent upon hormonic control, and until further selection has produced an oviduct that will efficiently perform the task that is demanded of it, it may be that those now in use should be conditioned by appropriate hormonic therapy. In any case it is the sex-physiologist's aid that is urgently demanded and not that of the pathologist.

The extension of the productive life of the individual is a matter of considerable importance. If, for example, it were possible to develop stocks of fowls which would maintain their first year's performance during a second and a third year, the whole structure of the industry would be altered. Greenwood's work seems to show that it is eminently possible by selection to achieve this objective, and all that is needed is a large-scale exploitation of the procedures already elaborated. In the meantime we must look to Cambridge and to Aberdeen for information concerning the possibility of extending the productive life by means of modifications in husbandry. In the rat it has been shown that the length of life can be extended by reducing the food intake, and in the fowl that neither the fastest nor the slowest growth-rates are compatible with maximum viability.

The attainment of early sexual maturity, the rhythm of the sexual cycle and through this the reproductive rate are qualities that can be manipulated genetically. But it takes time to " fix " these qualities in a stock. With recent advances in sex and reproductive physiology there has come into being the possibility of controlling them by other and simpler means. The syringe is replacing the seasons, for it is becoming possible by administering the appropriate hormones or their synthetic equivalents to exert a very complete control over the sexual and reproductive activities of our animals.

To me it seems that the time has now come when the live-stock industry must gain the power of controlling the secondary sex-ratio. It cannot much longer remain content to allow the numerical proportions of males and females among the newly-born in dairy herds of cattle and goats and in flocks of poultry to be decided by the operations of blind chance. Such power can be secured and, I think, should be secured. In the domesticated mammals this control, if Walton's work at Cambridge is adequately encouraged, will emerge from researches relating to the separations of the two kinds of spermatozoa. If I may be permitted to be prophetic, and at the same time assume that the policies and programmes of live-stock improvement in the immediate future will be born of a lively intelligence, I predict that the time will come when all the sires that will be used will be congregated in a few centres, and that the beribboned swaggering stallion will be seen no more upon our roads. He will give place to a small glass phial enclosed within a registered letter. Then the progeny test will claim a reliability that at present it cannot hope to possess. In the case of poultry the problem of the control of the secondary sex-ratio will

not so easily be solved, for here it is the female that elaborates the two kinds of gametes. In a poultry population, generally, it seems that there are two kinds of eggs : those, being fertilized, destined to yield males, and those which inevitably will develop into females, are elaborated in equal numbers. But careful search may be expected to disclose individuals which habitually yield a preponderance of females. In other forms " sex-ratio " genes have been identified and are known to disturb the mechanism responsible for the production of the two kinds of eggs. These genes can be incorporated into stocks by appropriate genetic procedures and by their aid a secondary sex-ratio of any desired dimension can be obtained. On the other hand, it may prove to be more desirable to transform the majority of male embryos into females during the earlier stages of incubation by means of injection of " feminizing " hormones into the egg. Undoubtedly this can be done, but it remains to be shown that such a procedure can with advantage be transferred from the laboratory to the farm.

The Breeder.—I will end as I began, by reminding myself and you that the geneticist knows that inborn qualities find full expression only in an optimum environment. The most important feature in the environment of our live stock is the breeder himself. The chief prerequisite in all live-stock improvement is improvement of the men in charge, the practitioners of agriculture, the veterinarians, and especially the improvement of privileged people like myself who are given such plentiful opportunities for self-expression and for public service. The need for new knowledge is urgent, but knowledge remains sterile and wasted until it can be exploited in the true service of mankind. No research is of any considerable value until its benefits can be appreciated by the actual practitioners. Science has contributions to offer, but only to the educated and intelligent. The chief obstacle to the application of genetic principles in live-stock breeding commonly seems to be the inability on the part of the breeder to understand the jargon of the geneticist. Yet the man to whom heterozygosity is a mystery and linkage a myth speaks familiarly of the most intricate details of a tractor.